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Boerstler

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(54) **MULTIPHASE RETIMING MECHANISM**

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- (52) **U.S. Cl.** **375/373; 327/146**
- (58) **Field of Search** **375/326, 327, 375/371, 373, 376; 370/516, 518; 327/144, 146, 147**

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(57) **ABSTRACT**

A system and method for reducing timing uncertainties in a serial data signal. A system may comprise a transmitter configured to transmit serial data to a receiver through a transmission medium. The receiver may comprise a retiming mechanism configured to sample the serial data using a particular phase of a clock at a point in time when the serial data signal may not be likely to experience jitter. The retiming mechanism may comprise a plurality of first units, e.g., flip-flops, where each of the first units is configured to sample the serial data using a particular phase of the clock. Each of the first units may be connected to a particular second unit, e.g., transmission gate. Each of the second units may be configured to output the value of the serial data sampled by the associated first unit upon activation. The data outputted may subsequently become part of the retimed data.

4 Claims, 7 Drawing Sheets

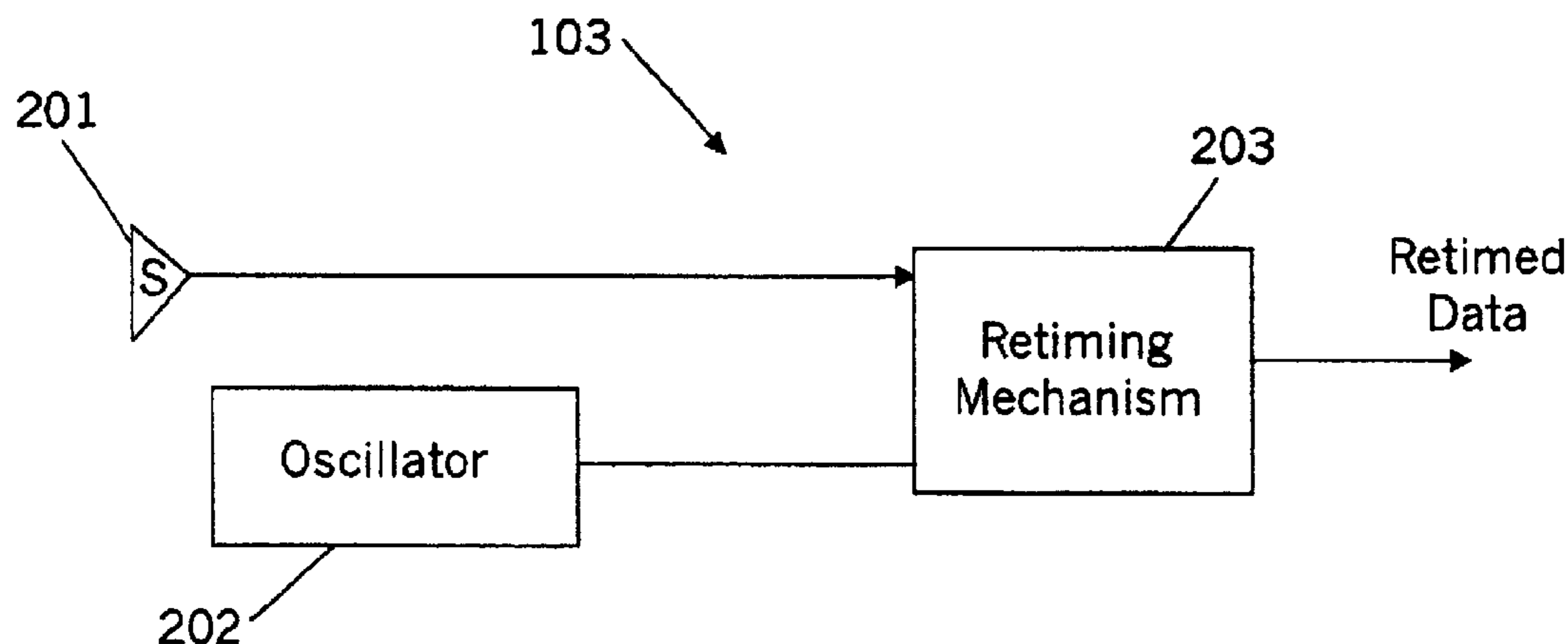


FIG. 1

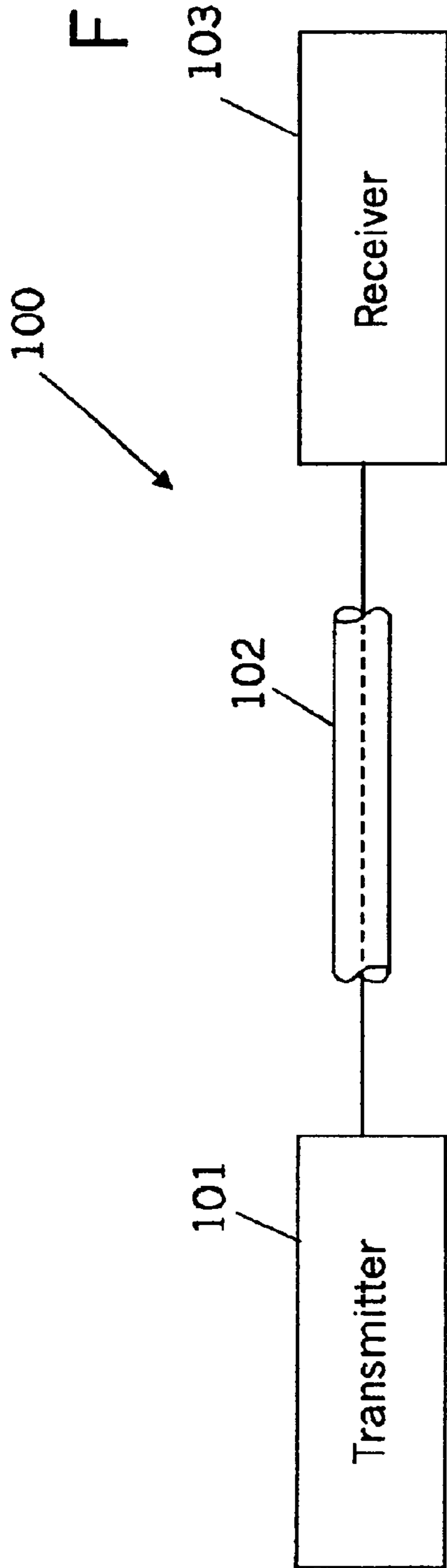


FIG. 2

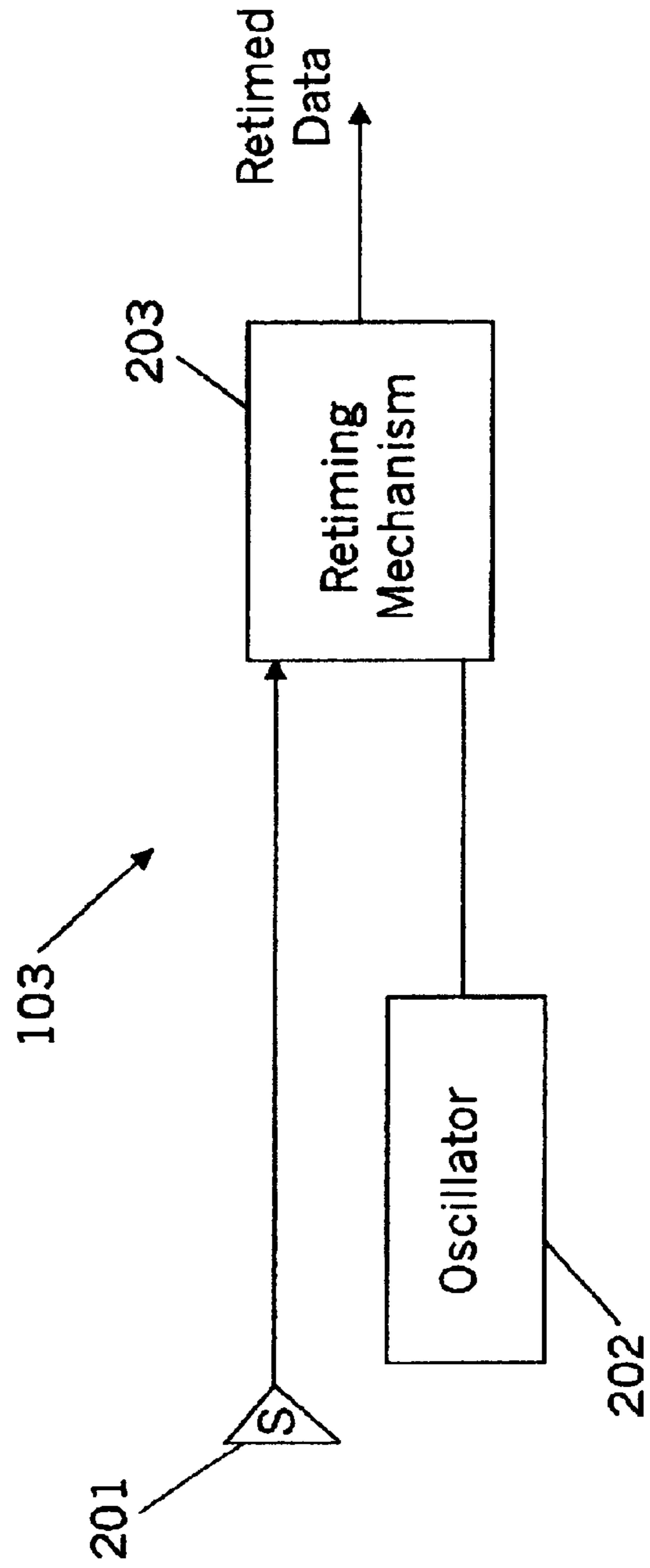


FIG. 3

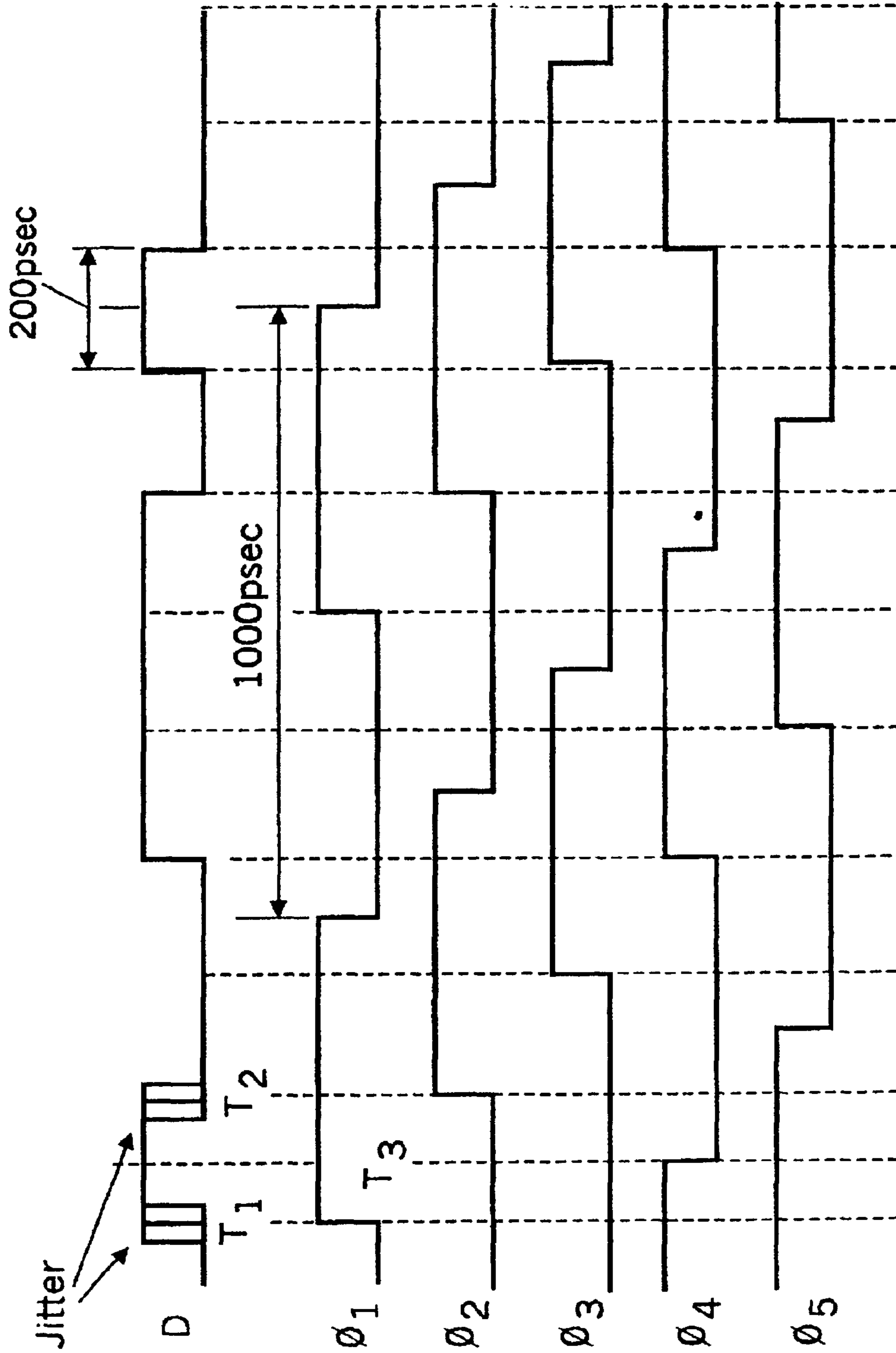


FIG. 4A

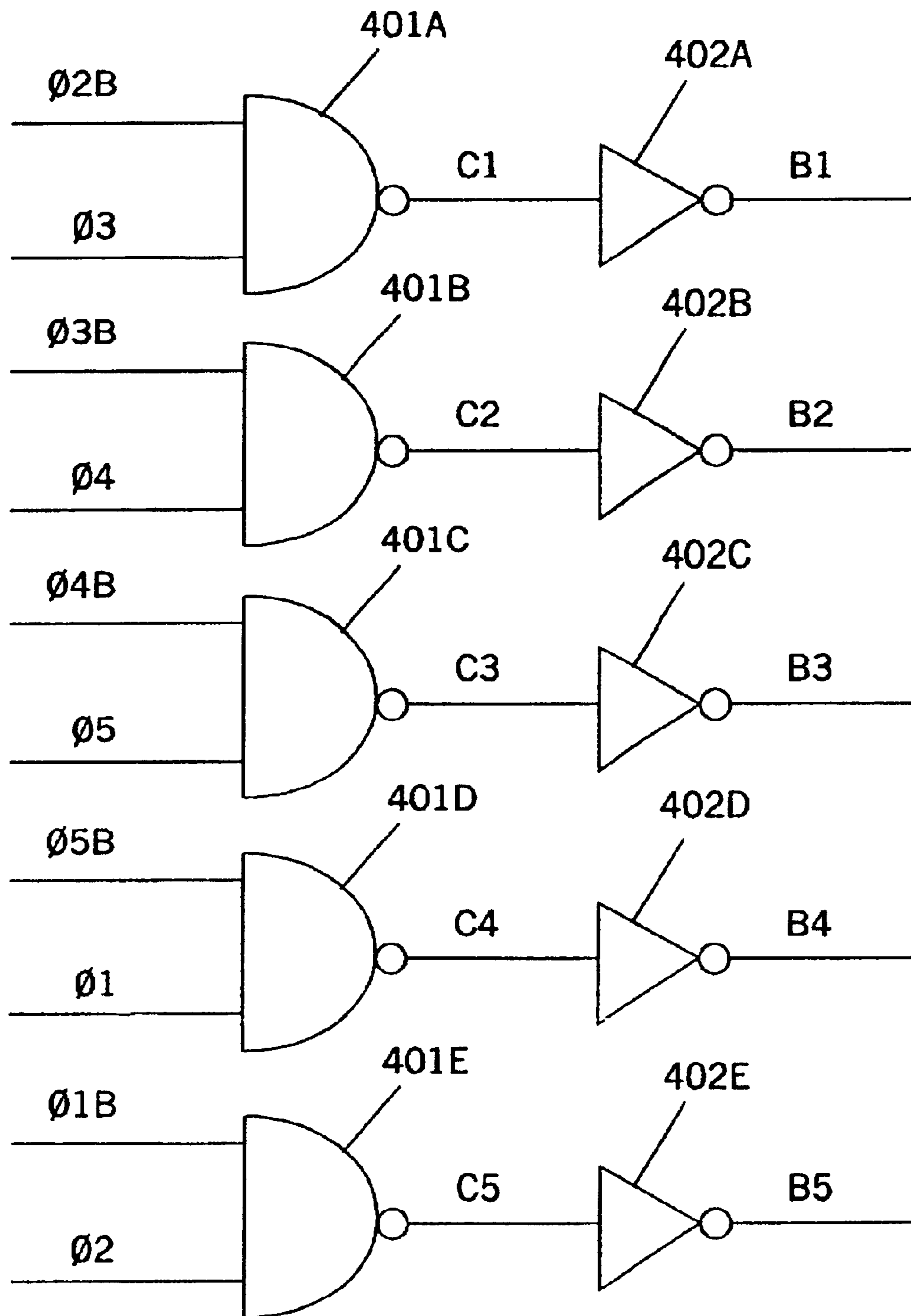


FIG. 4B

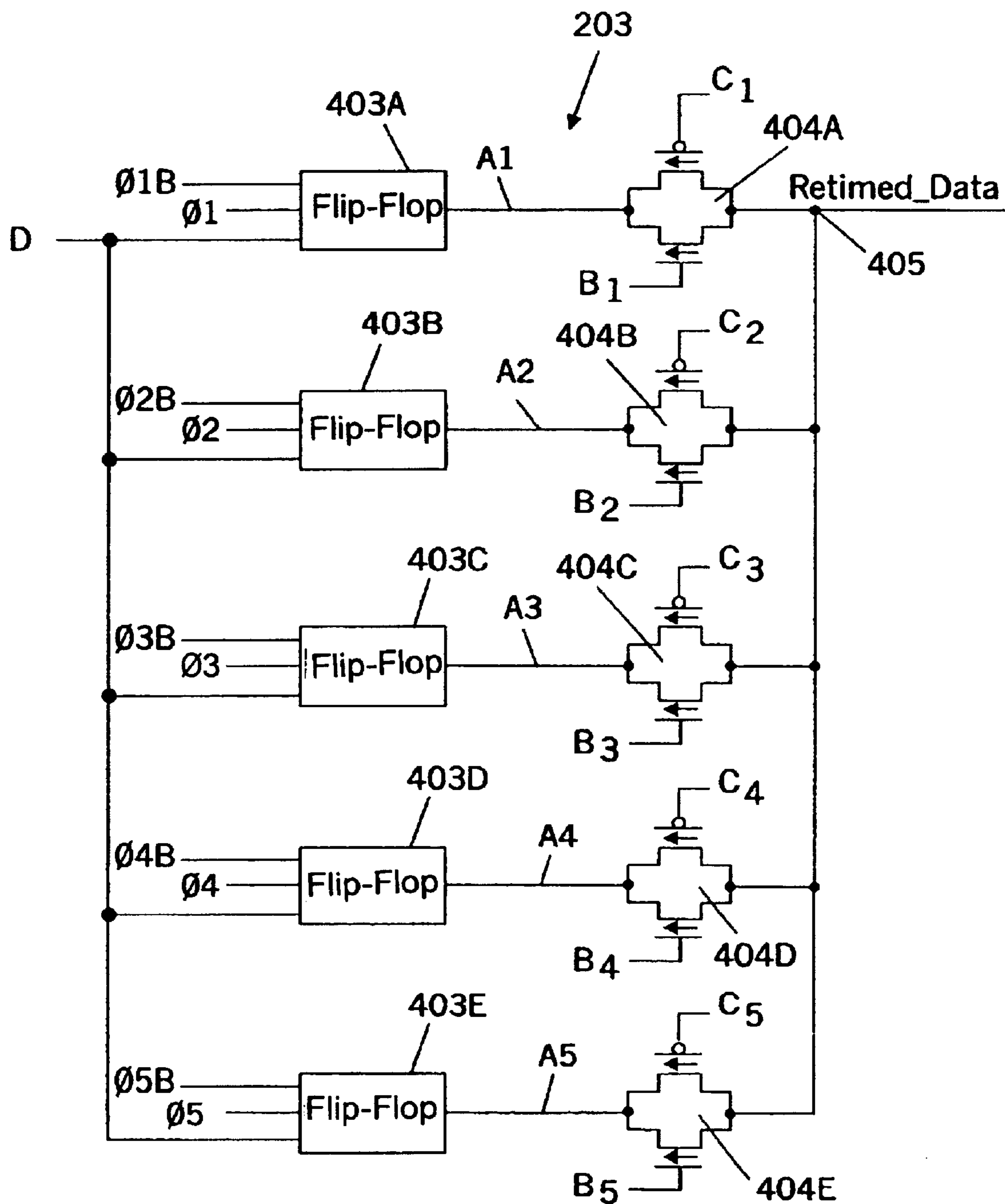


FIG. 5A

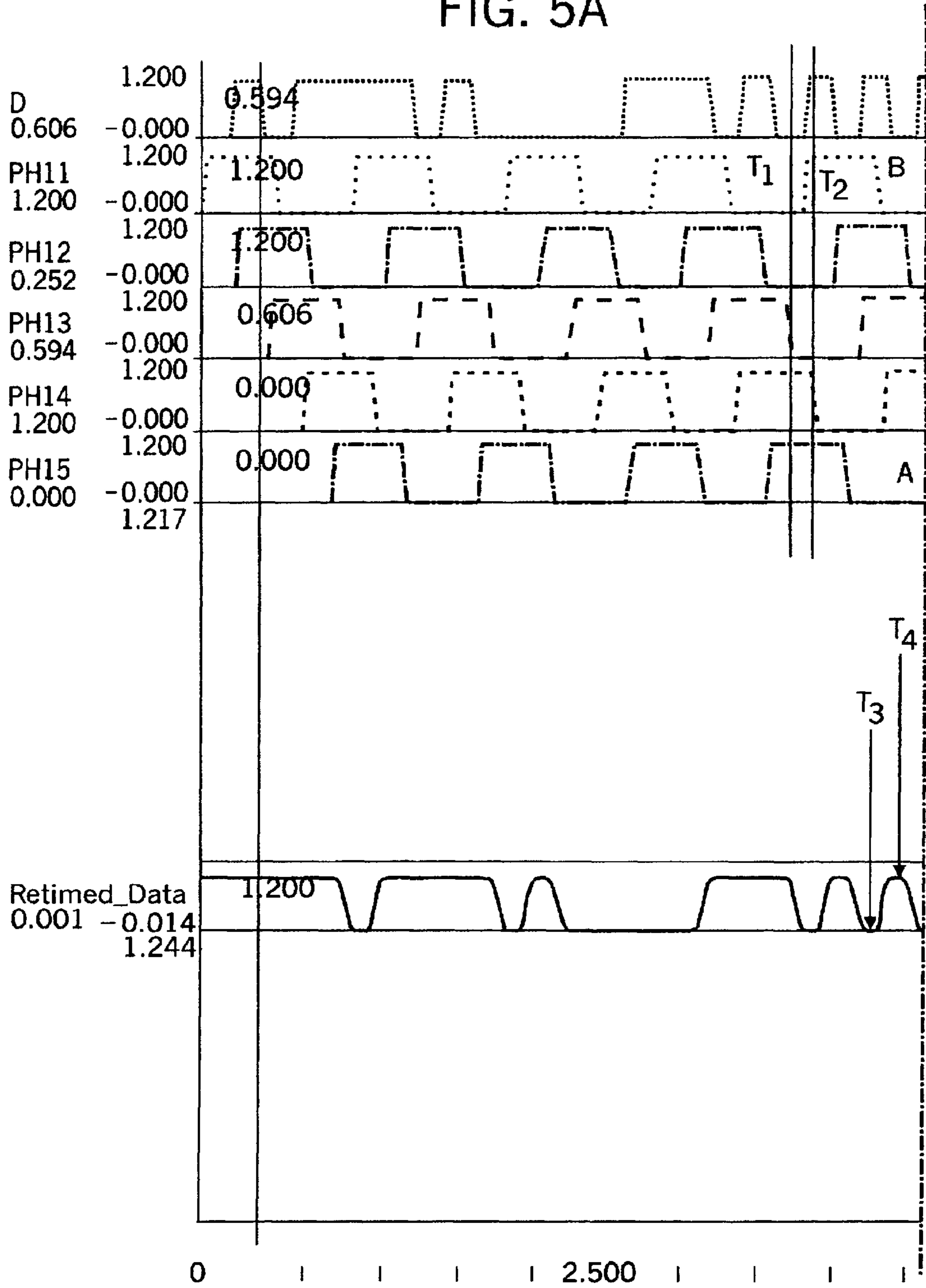


FIG. 5B

FIG. 5

| | |
|---------|---------|
| FIG. 5A | FIG. 5B |
|---------|---------|

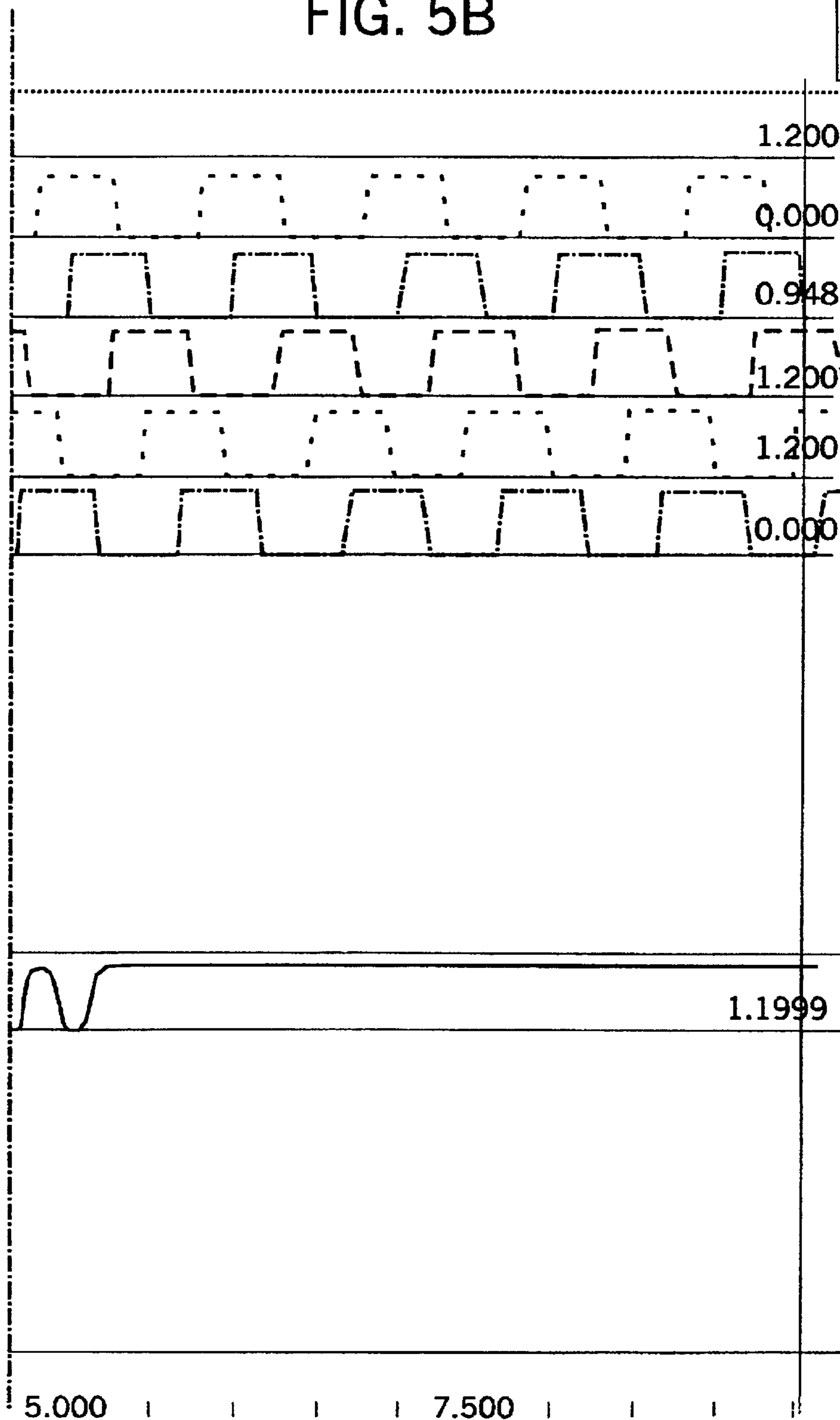
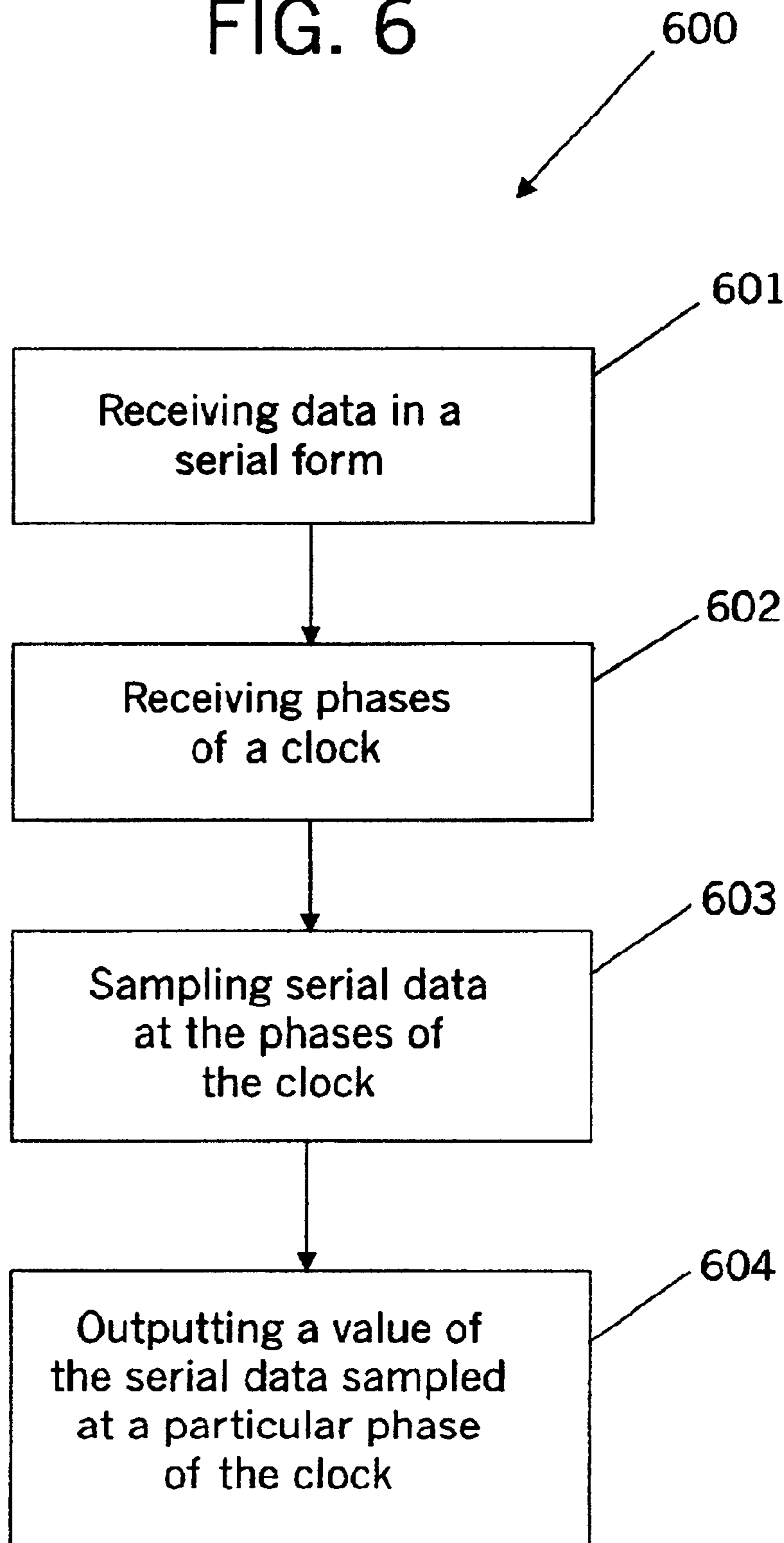


FIG. 6



MULTIPHASE RETIMING MECHANISM

CROSS REFERENCE TO RELATED APPLICATIONS

The present invention is related to the following U.S. Patent Applications which are incorporated herein by reference: Ser. No. 09/820,512 entitled "Synchronization State Detector" filed Mar. 29, 2001.

TECHNICAL FIELD

The present invention relates to the field of digital transmission, and more particularly to diminishing jitter in serialized data.

BACKGROUND INFORMATION

As electronic and computer technology continues to evolve, communication of information among different devices, either situated near by or at a distance becomes increasingly important. It is now more desirable than ever to provide high speed communications among different chips on a circuit board, different circuit boards in a system and different systems with each other. It is also desirable to provide high speed communications in intensive data consuming systems using graphical or video information, multiple input-output channels, local area networks, etc.

Data may be transmitted between different devices in a communication system through a "data link". Typically, data is transmitted in parallel whenever possible in order to increase bandwidth. However, due to cost, weight, interference (noise) and electrical loading considerations, parallel transmission is not feasible in many systems. In order to simplify the communications problem, data may be transmitted serially. By transmitting data serially, less hardware is required for the actual communications link between the different devices.

The transmitted serial data signal in the data link may have timing uncertainties as the result of interference, attenuation, skin effect, etc. These timing uncertainties are commonly referred to as "jitter." "Jitter" may refer to an offset of time as to when the serial data signal transitions from a high to a low state or from a low to a high state.

It would therefore be desirable to diminish jitter thereby improving the accuracy of the received serial data signal.

SUMMARY

The problems outlined above may at least in part be solved in some embodiments by reducing the timing uncertainties in the received serial data by a retiming mechanism configured to output a value of the serial data signal sampled at a particular phase of a clock at a point in time when the serial data signal may not be likely to experience jitter.

In one embodiment, a system for reducing timing uncertainties in a serial data signal comprises a transmitter configured to transmit serial data to a receiver through a transmission medium, e.g., wireless, wired. The receiver may comprise an input configured to receive serial data. The receiver may further comprise an oscillator configured to generate phases of a clock. The receiver may further comprise a retiming mechanism configured to receive the serial data as well as the phases of the clock generated by the oscillator. The retiming mechanism may be configured to reduce the timing uncertainties of the serial data by outputting a value of the serial data signal sampled at a particular phase of a clock at a point in time when the serial data signal may not be likely to experience jitter. The retiming mecha-

nism may comprise a plurality of first units, e.g., flip-flops, where each of the first units is configured to sample the serial data using a particular phase of the clock. Each of the first units may be connected to a particular second unit, e.g., transmission gate. Each of the second units may be configured to output the value of the serial data sampled by the associated first unit upon activation. The data outputted by the second units is the retimed data where the retimed data is the serial data with diminished timing uncertainties.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention can be obtained when the following detailed description is considered in conjunction with the following drawings, in which:

FIG. 1 illustrates an embodiment of the present invention of a serial data link;

FIG. 2 illustrates an embodiment of a receiver in a serial data link configured in accordance with the present invention;

FIG. 3 is a timing diagram illustrating the timing of the serial data and the phases of a clock according to the present invention;

FIGS. 4A and 4B illustrate an embodiment of the present invention of a retiming mechanism;

FIGS. 5A–B are a timing diagram illustrating the timing of the serial data, the phases of a clock and the retimed data according to the present invention; and

FIG. 6 is a flowchart of a method for reducing timing uncertainties in a serial data signal.

DETAILED DESCRIPTION

FIG. 1—Serial Data Link

FIG. 1 illustrates an embodiment of the present invention of a serial data link **100** used in a communication system. As stated in the Background Information, data may typically be transmitted between various devices in a communication system through a data link. Typically, data is transmitted in parallel whenever possible in order to increase bandwidth. However, due to cost, weight, interference (noise) and electrical loading considerations, parallel transmission is not feasible in many systems. In order to simplify the communications problem, data may be transmitted serially across a serial data link **100** by a transmitter **101**. Transmitter **101** may be configured to convert the parallel data to a serial form which may be transmitted through a medium **102**, e.g., wired, wireless, to a receiver **103** configured to convert the serial data into parallel form which may then be transmitted to another device, e.g., computer, cellular phone.

FIG. 2—Receiver

FIG. 2 illustrates an embodiment of the present invention of a receiver **103** configured to receive serial data **201** transmitted from transmitter **101** through medium **102**, e.g., wired, wireless. Receiver **103** may comprise an oscillator **202** configured to generate multiple phases of a clock. In one embodiment, oscillator **202** may be configured to operate at a frequency lower than the serial data rate thereby saving power. In the exemplary embodiment, oscillator **202** may be configured to generate five phases of a clock. It is noted that oscillator **202** may be configured to generate any number of phases of a clock. Serial data **201** as well as the multiple

phases of a clock generated by oscillator **202** may be inputted to a retiming mechanism **203**. Retiming mechanism **203** may be configured to retime, i.e., diminish jitter, the serial data signal **201** received from transmitter **101** as described with respect to of FIGS. 4–6.

As stated above, the serial data signal **201** generated by transmitter **101** may have timing uncertainties as the result of interference, attenuation, skin effect, etc. These timing uncertainties are commonly referred to as “jitter.” “Jitter” may refer to an offset of time as to when the serial data signal **201** transitions from a high to a low state or from a low to a high state as illustrated below.

FIG. 3—Timing Diagram

FIG. 3 is a timing diagram that illustrates the timing of serial data **201** and the phases of a clock generated by oscillator **202**. As stated above, in the exemplary embodiment, oscillator **202** generates five phases of a clock which are designated as $\emptyset 1$, $\emptyset 2$, $\emptyset 3$, $\emptyset 4$ and $\emptyset 5$.

As stated above, “jitter” may refer to timing uncertainties when the serial data signal **201** transitions from a high to a low state or from a low to a high state. Referring to FIG. 3, the serial data signal **201** experiences jitter at points in time at T1 and T2. That is, the serial data signal **201** experiences an offset of time at a point in time at T1 when the serial data signal **201** transitions from a low state to a high state and experiences an offset of time at a point in time at T2 when the serial data signal **201** transitions from a high state to a low state.

In one embodiment, jitter may be diminished by sampling the serial data signal **201** at a point in time when the serial data signal **201** is not likely to experience jitter. For example, if the serial data signal **201** were sampled during a particular period at a particular point in time, such as at T3, then jitter may be diminished. The serial data signal **201** may be sampled by using an appropriate phase, e.g., $\emptyset 1$, $\emptyset 2$, $\emptyset 3$, $\emptyset 4$, $\emptyset 5$, of the clock generated by oscillator **202**. For example, the serial data signal **201** may be sampled at the point in time at T3 by using phase $\emptyset 4$ since the falling edge of phase $\emptyset 4$ is aligned with the point in time at T3. A retiming mechanism **203** using the phases of the clock generated by oscillator **202** may be configured to sample serial data **201** at a point in time when the serial data signal **201** is not likely to experience jitter, e.g., T3, using an appropriate phase, e.g., $\emptyset 4$, of the clock as described below.

FIGS. 4A and 4B—Retiming Mechanism

FIGS. 4A and 4B illustrate one embodiment of the present invention of retiming mechanism **203**. Referring to FIG. 4B, retiming mechanism **203** may comprise a plurality of flip-flops **403A–E** configured to sample serial data **201** at various phases of the clock generated by oscillator **202** as described in further detail below. Flip-flops **403A–E** may collectively or individually be referred to as flip-flops **403** or flip-flop **403**, respectively. In the exemplary embodiment, flip-flops **403** are D flip-flops. Retiming mechanism **203** may further comprise a plurality of transmission gates **404A–E**. A transmission gate may refer to two transistors of opposite types, e.g., p-type, n-type, coupled to one another. Transmission gates **404A–E** may collectively or individually be referred to as transmission gates **404** or transmission gate **404**, respectively. Referring to FIG. 4A, retiming mechanism **203** may further comprise combinational logic, e.g., plurality of NAND gates **401A–E** and a plurality of inverters **402A–E**, configured to generate the logical states of the inputs to transmission gates **404A–E**. NAND gates **401A–E** may collectively or individually be referred to as NAND gates **401** or NAND gate **401**, respectively. Inverters **402A–E** may collectively or individually be referred to as inverters **402** or

inverter **402**, respectively. It is noted that retiming mechanism **203** may comprise a different number of flip-flops **403** and a different number of transmission gates and a different number of NAND gates **401** and a different number of inverters **402** corresponding to a different number of phases of the clock generated by oscillator **202** and that FIGS. 4A and 4B are illustrative.

Referring to FIG. 4B, flip-flops **403** are configured to sample serial data **201** at an edge, e.g., negative edge, of a particular phase, e.g., $\emptyset 1$. For example, flip-flop **403A** may be configured to receive as inputs phase $\emptyset 1$, the complement of phase $\emptyset 1$ ($\emptyset 1B$) and serial data **201** thereby being able to sample serial data **201** using an edge, e.g., negative edge, of phase $\emptyset 1$. Flip-flop **403B** may be configured to receive as inputs phase $\emptyset 2$, the complement of phase $\emptyset 2$ ($\emptyset 2B$) and serial data **201** thereby being able to sample serial data **201** using an edge, e.g., negative edge, of phase $\emptyset 2$. Flip-flop **403C** may be configured to receive as inputs phase $\emptyset 3$, the complement of phase $\emptyset 3$ ($\emptyset 3B$) and serial data **201** thereby being able to sample serial data **201** using an edge, e.g., negative edge, of phase $\emptyset 3$. Flip-flop **403D** may be configured to receive as inputs phase $\emptyset 4$, the complement of phase $\emptyset 4$ ($\emptyset 4B$) and serial data **201** thereby being able to sample serial data **201** using an edge, e.g., negative edge, of phase $\emptyset 4$. Flip-flop **403E** may be configured to receive as inputs phase $\emptyset 5$, the complement of phase $\emptyset 5$ ($\emptyset 5B$) and serial data **201** thereby being able to sample serial data **201** using an edge, e.g., negative edge, of phase $\emptyset 5$.

Data sampled by flip-flops **403A–E** is outputted to nodes **A1–A5**, respectively. The data at **A1** may be outputted to node **405** if transmission gate **404A** associated with flip-flop **403A** is activated, i.e., turned on. The data at **A2** may be outputted to node **405** if transmission gate **404B** associated with flip-flop **403B** is activated, i.e., turned on. The data at **A3** may be outputted to node **405** if transmission gate **404C** associated with flip-flop **403C** is activated, i.e., turned on. The data at **A4** may be outputted to node **405** if transmission gate **404D** associated with flip-flop **403D** is activated, i.e., turned on. The data at **A5** may be outputted to node **405** if transmission gate **404E** associated with flip-flop **403E** is activated, i.e., turned on. A particular transmission gate **404**, e.g., transmission gate **404C**, may be activated based upon the logical states of the inputs as determined by the combinational logic in retiming mechanism, e.g., plurality of NAND gates **401** and a plurality of inverters **402**, as described further below.

As stated above, transmission gates **404** may be two transistors of opposite types, e.g., p-type, n-type, coupled to one another. For example, transmission gate **404A** may comprise a p-type transistor that receives as input the logical state of **C1** and a n-type transistor that receives as input the logical state of **B1**. Transmission gate **404B** may comprise a p-type transistor that receives as input the logical state of **C2** and a n-type transistor that receives as input the logical state of **B2**. Transmission gate **404C** may comprise a p-type transistor that receives as input the logical state of **C3** and a n-type transistor that receives as input the logical state of **B3**. Transmission gate **404D** may comprise a p-type transistor that receives as input the logical state of **C4** and a n-type transistor that receives as input the logical state of **B4**. Transmission gate **404E** may comprise a p-type transistor that receives as input the logical state of **C5** and a n-type transistor that receives as input the logical state of **B5**.

Transmission gate **404** may be activated when the input to the p-type transistor is low and the input to the n-type transistor is high. When that occurs, the output of the flip-flop **403** associated with that transmission gate **404** is

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outputted to node **405** and subsequently becomes part of the retimed_data, i.e., the data after sampling the serial data signal **201** at a point in time when the serial data signal **201** is not likely to experience jitter. For example, when the logical state of **C1** is low and the logical state of **B1** is high, the data at **A1** is outputted to node **405** and subsequently becomes part of the retimed_data.

As stated above, the logical states of the inputs, e.g., **C1–C5**, **B1–B5**, to transmission gates **404** may be generated by the combinational logic, e.g., plurality of NAND gates **401** and a plurality of inverters **402**, in retiming mechanism **203**. Referring to FIG. 4A, NAND gate **401A** generates the logical state of **C1** based on the inputs of $\emptyset 2B$ and $\emptyset 3$ where $\emptyset 2B$ is the complement of the phase $\emptyset 2$. Subsequently, **C1** is low only when both inputs $\emptyset 2B$ and $\emptyset 3$ are high. In other cases, **C1** is high. NAND gate **401B** generates the logical state of **C2** based on the inputs of $\emptyset 3B$ and $\emptyset 4$ where $\emptyset 3B$ is the complement of the phase $\emptyset 3$. Subsequently, **C2** is low only when both inputs $\emptyset 3B$ and $\emptyset 4$ are high. In other cases, **C2** is high. NAND gate **401C** generates the logical state of **C3** based on the inputs of $\emptyset 4B$ and $\emptyset 5$ where $\emptyset 4B$ is the complement of the phase $\emptyset 4$. Subsequently, **C3** is low only when both inputs $\emptyset 4B$ and $\emptyset 5$ are high. In other cases, **C3** is high. NAND gate **401D** generates the logical state of **C4** based on the inputs of $\emptyset 5B$ and $\emptyset 1$ where $\emptyset 5B$ is the complement of the phase $\emptyset 5$. Subsequently, **C4** is low only when both inputs $\emptyset 5B$ and $\emptyset 1$ are high. In other cases, **C4** is high. NAND gate **401E** generates the logical state of **C5** based on the inputs of $\emptyset 1B$ and $\emptyset 2$ where $\emptyset 1B$ is the complement of the phase $\emptyset 1$. Subsequently, **C5** is low only when both inputs $\emptyset 1B$ and $\emptyset 2$ are high. In other cases, **C5** is high. The logical states of **C1–C5** are inverted by inverters **402A–E** to produce the logical states of **B1–B5**, respectively. The logical states of **B1–B5** are complements of the logical states of **C1–C5**, respectively.

As stated above, a particular transmission gate, e.g., **404C**, may be activated based upon the logical states of the inputs as determined by the combinational logic, e.g., plurality of NAND gates **401** and a plurality of inverters **402**, in retiming mechanism as illustrated in FIG. 4A.

FIGS 5A–B—Timing Diagram

FIGS. 5A–B are a timing diagram that illustrate the timing of serial data **201**, the phases of the clock generated by oscillator **202** as well as the retimed data where the retimed data is the serial data signal **201** with diminished timing uncertainties.

For example, at the point in time at **T1**, phase $\emptyset 3$ is the appropriate phase to use to sample the serial data signal **201** since the falling edge of phase $\emptyset 3$ is aligned with the point in time at **T1**. Referring to FIGS. 4A, 4B, 5A and 5B, when the logical state of phase $\emptyset 3$ becomes low, flip-flop **403C** sampling the serial data signal **201** using phase $\emptyset 3$ of the clock generated by oscillator **202** outputs the sampled serial data signal **201** to **A3**. The value of the sampled serial data signal **201** at **A3** will be outputted to node **405** when the logical state of **C3** is low and the logical state of **B3** is high thereby activated transmission gate **404C**. The logical state of **C3** is low and the logical state of **B3** is high when the inputs to NAND gate **401C**, $\emptyset 4B$ and $\emptyset 5$, are both high. That is, the logical state of **C3** is low and the logical state of **B3** is high when the logical state of phase $\emptyset 4$ is low and the logical state of phase $\emptyset 5$ is high. That occurs during the shaded region labeled “A” as illustrated in FIG. 5A. The value of the sampled serial data signal **201** at **A3** that was outputted to node **405** upon activation of transmission gate **404C** subsequently becomes part of the retimed_data as illustrated in FIG. 5A at the point in time at **T3**.

At the point in time at **T2**, phase $\emptyset 4$ is the appropriate phase to use to sample the serial data signal **201** since the

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falling edge of phase $\emptyset 4$ is aligned with the point in time at **T2**. Referring to FIGS. 4A, 4B, 5A and 5B, when the logical state of phase $\emptyset 4$ becomes low, flip-flop **403D** sampling the serial data signal **201** using phase $\emptyset 4$ of the clock generated by oscillator **202** outputs the sampled serial data signal **201** to **A4**. The value of the sampled serial data signal **201** at **A4** will be outputted to node **405** when the logical state of **C4** is low and the logical state of **B4** is high thereby activated transmission gate **404D**. The logical state of **C4** is low and the logical state of **B4** is high when the inputs to NAND gate **401D**, $\emptyset 5B$ and $\emptyset 1$, are both high. That is, the logical state of **C4** is low and the logical state of **B4** is high when the logical state of phase $\emptyset 5$ is low and the logical state of phase $\emptyset 1$ is high. That occurs during the shaded region labeled “B” as illustrated in FIG. 5A. The value of the sampled serial data signal **201** at **A4** that was outputted to node **405** upon activation of transmission gate **404D** subsequently becomes part of the retimed_data as illustrated in FIG. 5A at the point in time at **T4**.

FIG. 6—Method for Reducing Timing Uncertainties in a Serial Data Signal

FIG. 6 illustrates a flowchart of one embodiment of the present invention of a method **600** for reducing timing uncertainties, i.e., jitter, in serial data signal **201**. In step **601**, receiver **103** (FIG. 1) may comprise a retiming mechanism **203** (FIG. 2) configured to receive serial data **201** transmitted from transmitter **101** (FIG. 1). In step **602**, retiming mechanism **203** in receiver **103** may further be configured to receive phases of a clock generated from an oscillator **202** (FIG. 2) in receiver **103**. In one embodiment, oscillator **202** may be configured to operate at a frequency lower than the serial data rate thereby saving power.

In step **603**, serial data **201** may be sampled at various phases of the clock generated by oscillator **202** by a plurality of flip-flops **403** (FIG. 4B) in retiming mechanism **203** as described in the description of FIGS. 4A and 4B. By sampling the serial data signal **201** at various phases of the clock generated by oscillator **202**, the serial data signal **201** may be sampled at points in time when the serial data signal **201** may not be likely to experience jitter as illustrated in FIG. 3. Each particular flip-flop **403** may be associated with a particular transmission gate **404** (FIG. 4B) as illustrated in FIG. 4B.

In step **604**, the value of the serial data sampled by a particular flip-flop **403** at a particular phase of the clock may be outputted to become part of the retimed data if the associated transmission gate **404** is activated as described in the description of FIGS. 4A and 4B. Transmission gate **404** may be activated based upon the logical states of its inputs as determined by the combinational logic in retiming mechanism **203**, e.g., plurality of NAND gates **401** and a plurality of inverters **402**, as described in the description of FIGS. 4A and 4B and illustrated in FIG. 5.

It is noted that steps **601–604** in method **600** may be executed in a different order than presented and that the order presented in the discussion of FIG. 6 is illustrative. It is further noted that certain steps in steps **601–604**, e.g., steps **601** and **602**, may occur almost concurrently.

Although the system and method are described in connection with several embodiments, it is not intended to be limited to the specific forms set forth herein, but on the contrary, it is intended to cover such alternatives, modifications, and equivalents, as can be reasonably included within the spirit and scope of the invention as defined by the appended claims. It is noted that the headings are used only for organizational purposes and not meant to limit the scope of the description or claims.

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I claim:

1. A receiver comprising:
 - an oscillator outputting three or more phases of a clock signal; and
 - a retiming mechanism coupled to said oscillator having circuitry for receiving said phases of said clock signal and serial data, and circuitry operable to reduce timing uncertainties in said serial data by outputting a value of said serial data sampled at a particular phase of said clock signal;
 - wherein said retiming mechanism comprises a plurality of first units, wherein each of said plurality of first units comprises circuitry for sampling said serial data using a said particular phase of said clock signal;
 - wherein said retiming mechanism further comprises a plurality of second units, wherein each of said plurality of second units is associated with a particular first unit, wherein each of said plurality of second units comprises circuitry for outputting the value of said serial data sampled by said associated first unit upon activation;
 - wherein a particular second unit of said plurality of second units is activated based on a logical state of each input to said particular second unit; and
 - wherein said logical state of each input is determined based on combinational logic using said phases of said clock signal and complements of said phases of said clock signal.
2. The receiver as recited in claim 1, wherein each of said plurality of first units comprises circuitry for receiving said particular phase of said clock signal and a complement of said particular phase of said clock signal and said serial data.
3. A system comprising:
 - a transmission medium;
 - a transmitter coupled to said transmission medium configured to convert parallel data to a serial form; and

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- a receiver coupled to said transmission medium, wherein said receiver comprises:
 - an oscillator outputting three or more phases of a clock signal; and
 - a retiming mechanism coupled to said oscillator having circuitry for receiving said phases of said clock signal and serial data, and circuitry operable to reduce timing uncertainties in said serial data by outputting a value of said serial data sampled at a particular phase of said clock signal;
 - wherein said retiming mechanism comprises a plurality of first units, wherein each of said plurality of first units comprises circuitry for sampling said serial data using said particular phase of said clock signal;
 - wherein said retiming mechanism further comprises a plurality of second units, wherein each of said plurality of second units is associated with a particular first unit, wherein each of said plurality of second units comprises circuitry for outputting the value of said serial data sampled by said associated first unit upon activation;
 - wherein a particular second unit of said plurality of second units is activated based on a logical state of each input to said particular second unit; and
 - wherein said logical state of each input is determined based on combinational logic using said phases of said clock signal and complements of said phases of said clock signal.
- 4. The system as recited in claim 3, wherein each of said plurality of first units comprises circuitry for receiving said particular phase of said clock signal and a complement of said particular phase of said clock signal and said serial data.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,963,628 B2
DATED : November 8, 2005
INVENTOR(S) : David William Boerstler

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It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 3,

Line 47, insert -- . -- after "203" and before "Reffering".

Column 7,

Line 15, delete "a".

Signed and Sealed this

Sixteenth Day of May, 2006

A handwritten signature in black ink on a dotted background. The signature reads "Jon W. Dudas" in a cursive style.

JON W. DUDAS

Director of the United States Patent and Trademark Office